Evaluating the Ocean Observing System: Surface Currents

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Project Summary

The Integrated Ocean Observing System (IOOS) includes an array of moored and drifting buoys that measure SST and near-surface currents throughout the world's oceans. The success of the IOOS in resolving SST variations and reducing satellite SST bias is quantified in a NESDIS quarterly report. However, until this project was initiated, no comparable evaluation was performed for surface currents even though surface currents carry massive amounts of heat from the tropics to subpolar latitudes, leading (and potentially improving prediction of) SST anomalies. Current anomalies can also be an early indicator of phase shifts in the ENSO, NAO, and possibly other climate cycles. The GOOS/GCOS (1999) report specified that the IOOS should resolve surface currents at 2 cm/s accuracy, with one observation per month at a spatial resolution of 600 km. The goal of this project is to maintain a quarterly "Observing System Status Report for Surface Currents", which evaluates how well the IOOS satisfied these requirements. This product is being used as a guide for future drifter deployments in conjunction with NOAA/AOML's Drifter Operations Center, a branch of the Global Drifter Program, and may demonstrate where future moored observations are necessary in order to meet these requirements. As a part of this report, we will quantify the global mean bias in satellite-based estimates of surface currents, analogous to the evaluation done for SST measurements.

For many years, spatio-temporally dense satellite observations of SST have been calibrated with the sparser but direct set of in-situ observations to produce operational SST products. The potential biases in these data have been carefully quantified (Zhang et al., 2004) and the observing system's performance is measured in these terms by NESDIS. Many researchers routinely calculate surface currents from satellite observations of wind and altimetry; geostrophic currents derived from blended satellite altimetry fields are already being estimated at AOML and posted daily in near-real time at http://www.aoml.noaa.gov/phod/trinanes/java.html. However, careful, quantified comparison with the in-situ observations has only been published for a few regions such as the Kuroshio Extension (Niiler et al., 2003). No one has yet performed this comparison globally using non-interpolated altimetry, and the observing system is not evaluated in this context.

In this project, we have begun generating a product that evaluates the success of the observing system in satisfying GOOS/GCOS requirements for surface current observations, on a quarterly basis. Surface current measurements are collected by drogued drifting buoys and by moorings with a near-surface point acoustic current meter. As seen in the FY06 quarterly report (Fig. 1), we present the spatial coverage of these measurements for that quarter (top right), the spatial distribution of success at meeting GOOS/GCOS requirements (bottom left, requirements stated in top left panel), and a time series showing the month-by-month fraction of the world's oceans that were measured at the resolution and accuracy stated by these requirements (bottom right).

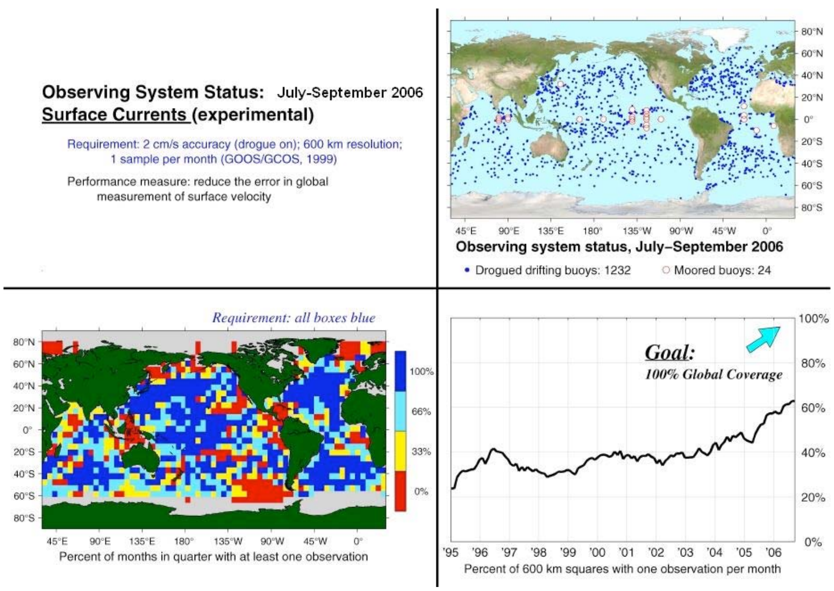


Fig. 1: FY06 Q4 report evaluating the IOOS's performance for near surface current measurements.

Accomplishments

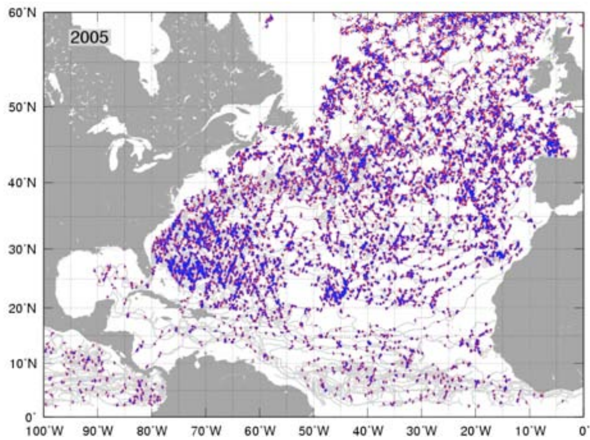
Near-real time drifter data is obtained at weekly resolution from the Global Drifter Program's drifter Data Assembly Center (DAC). The DAC identifies drifters which have run aground or been picked up, and removes these from the data stream. The DAC separate maintains a META file documenting the drogue-off date (date when each drifter lost its sea anchor). When a drifter has lost its drogue, it is significantly affected by direct wind forcing and no longer satisfies the GOOS/GCOS quality requirement for surface current measurements. We thus merge these two data sets to eliminate drogue-off drifters from our analysis.

Moored current measurements are collected by near-surface point acoustic meters on the Tropical Atmosphere-Ocean (TAO) array in the Pacific, the Pilot Research Array in the Tropical Atlantic (PIRATA), the sustained array of ATLAS moorings in the tropical Indian Ocean, and the Kuroshio Extension Observatory (KEO) mooring at 32.3ºN, 144.5ºE. Currents at daily resolution are downloaded from the TAO Project Office each quarter to quantify the number of observations at each site, and the TAO office separately provides their record of days of observations per site. Each quarter, these independent measures are compared to ensure accuracy.

Each quarter, we crate an integrated data set of surface current observations by merging the drifting and moored buoy data; we then analyze these data in 600km squares to evaluate the IOOS for surface current measurements according to the GOOS/GCOS requirements.

Since the project was initiated at the beginning of FY06, quarterly reports have been produced within two weeks of each quarter's end. These reports are e-mailed to the Office of Climate Observations for their web site at:
http://www.oco.noaa.gov/index.jsp?show_page=page_status_reports.jsp&nav=observing, and are separately archived on the AOML "State of the Ocean" site at:
http://www.aoml.noaa.gov/phod/soto/gsc/index.php. We have also created backdated reports starting from January—March 2005.

To derive the bias in satellite-based estimates of surface currents, we are comparing altimetry-derived geostrophic velocity anomalies to coincident cross-track drifter speeds, with the Ekman component (using the Ralph and Niiler 1999 parameterization) removed. By doing this comparison with cross-track speeds from individual altimetric passes, rather than using a gridded altimetric product, we will be able to assess the accuracy of a satellite-based product independent of mapping errors in a gridded product. In short, a comparison of gridded altimetry vs. drifters does not tell us how the errors are distributed for cross-track vs. along-track speeds, and they do not tell us how the global bias may change if a different number of altimeters are flying. Our analysis will permit the global bias to be characterized by the current IOOS coverage for 100% altimetric coverage, for the actual present altimetric coverage, and could be used to quantify the impact on surface current estimates if an altimeter were to fail or be added.



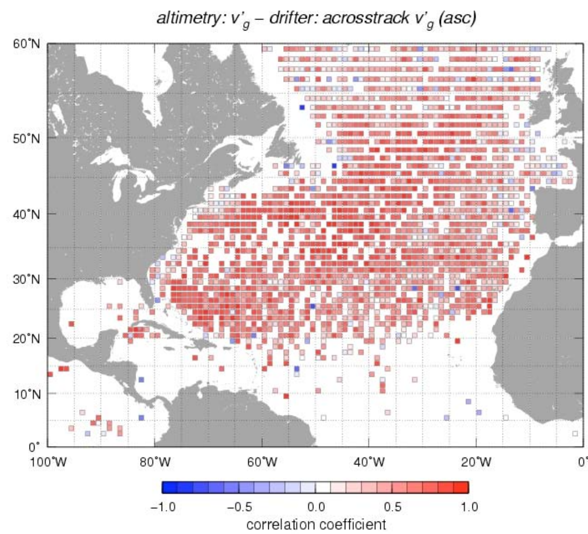


Fig. 2: Left: Locations of all coincident measurements where across-track altimetry-derived geostrophic velocity anomalies (red) are match with the drifter geostrophic velocity anomalies (blue) during 2005. The drifter values were computed by removing the Ekman component, which was estimated from NCEP winds. Right: mean correlation between drifter and altimetry geostrophic velocity anomalies, averaged in 1° bins, for the time period October 1992—March 2006. Correlations are computed when the number of observations in the bins is larger than 15.

Preliminary results (Fig. 2) have focused on the North Atlantic, with FY07 plans to expand the results globally. These results, in particular the high correlation between drifter- and altimetry-derived geostrophic currents in the subtropical North Atlantic, demonstrate the ability to explain a majority of the surface current variance from altimetry with high skill. However, the correlation tends to decrease at subpolar latitudes, where sustained drifter observations are needed to eliminate biases or errors in the satellite-based estimates. At low latitudes (0-20°N) and in the Gulf of Mexico, there are currently an insufficient number of observations to compute robust correlations at 1° resolution. In these two regions more drifter observations are needed to be able to produce more matches between altimetry and drifter observations at 1° resolution. Maps of the bias between total drifter velocity and the altimetric geostrophic velocity anomaly (not shown) clearly show the time-mean currents, while the bias between drifter-derived and altimetric-derived geostrophic velocity anomaly reveal unexpected patterns that appear to be associated with Gulf Stream meanders or rings, but must be explored more carefully.

<u>Publications and Reports</u>:

- Lumpkin, R. and G. J. Goni, 2006: Global oceans: Surface currents. In *State of the Climate in 2005*, K.A. Shein, A.M. Waple, H.J. Diamond, and J.M. Levy (eds.). Bulletin of the American Meteorological Society, **87**(6), S25-S26.

- Lumpkin, R. and G. J. Goni, 2006: Surface currents. In *Annual Report on the State of the Ocean and the Ocean Observing System for Climate (FY-2005),* J.M. Levy, D.M. Stanitski, and P. Arkin (eds.). NOAA Office of Climate Observation, Silver Spring, MD, 61-67.